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Supplementary File 2: R code used for the SITAR analysis

```
rm(list=ls(all=TRUE))

require(gamlss, haven, foreign, sitar, fdapace, hbgd, dplyr, ggplot2, ggpubr, growthstandards, PerformanceAnalytics)

# install.packages("remotes") # if "remotes" is not already installed

# remotes::install_github("ki-tools/growthstandards")


#### DHS HEIGHT DATA ####

dhs <- read.dta("DHS_ALL_DATA_WHO.dta") # Read DHS data

# Males

dhs_b <- subset(dhs, sex=="male") # selects male height

dhs_b$year <- as.factor(dhs_b$year) #sets year as a factor variable

dhs_b$country <- as.factor(dhs_b$country) #sets country as a factor variable

# Determining the appropriate number of degrees of freedom (knots)

dfset(ageint_mths, height, dhs_b, FUN=BIC, plot=TRUE) # untransformed age: df = 11

dfset(log(ageint_mths), height, dhs_b, FUN=BIC, plot=TRUE) # log-transformed age: df = 4


# fit sitar model of height vs log-transformed age

# checking the influence of each SITAR parameter

m1 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_b, random='a')

# fits sitar using 'a' as fixed and random effect


m2 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_b, fixed='a+c', random='a+c')

# fits sitar using 'a+c' as fixed and random effects
```

```
m3 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_b, random='a+c')

# fits sitar using 'a+c' as fixed and random effects



# male <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_b,random='a+b+c')

# fits sitar using 'a+b+c' as fixed and random effects # Did not converge


summary(m3)

intervals(m3) # generates the 95% CI for the SD of random effects


# Females

dhs_g <- subset(dhs, sex=="female") # selects female height

dhs_g$year <- as.factor(dhs_g$year)

dhs_g$country <- as.factor(dhs_g$country)


# Determining the appropriate number of degrees of freedom (knots)

dfset(ageint_mths, height, dhs_g, FUN=BIC, plot=TRUE) # untransformed age: df = 11

dfset(log(ageint_mths), height, dhs_g, FUN=BIC, plot=TRUE) # log-transformed age: df = 4

# fit sitar model of height vs log-transformed age

# checking the influence of each SITAR parameter

m4 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_g, random='a')

# fits sitar using 'a' as fixed and random effect

m5 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_g, fixed='a+c', random='a+c')

# fits sitar using 'a+c' as fixed and random effects
```

```
m6 <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_g, random='a+c')

# fits sitar using 'a+c' as fixed and random effects

# female <- sitar(x=log(ageint_mths), y=height, id=id, df=4, data=dhs_g,random='a+b+c')

# fits sitar using 'a+b+c' as fixed and random effects

summary(m6)

intervals(m6) # generates the 95% CI for the SD of random effects

varexp(pattern='m') # variance explained by each model

BICadj(pattern='m') # BIC for each model

AICadj(pattern='m') # AIC for each model

# Models m3 for boys and m6 for girls selected as final models


## Figure 2

par(mfrow=c(2,2))

mplot(x = ageint_mths, y = height, id = id, vlim=c(50, 120), xlim=c(0,60),data = dhs_b, col = id,
las = 1, axes=FALSE,

      ylab="Height (cm)", xlab="Age in months",main="Boys height: raw")

axis(side=1, at=seq(0, 60, by=12))

axis(side=2, at=seq(50, 120, by=20),las=1)


plot(m3, opt = 'a', col = id, vlim=c(50, 120), xlim=c(0,60),las = 1, axes=FALSE,

     ylab="Height (cm)", xlab="Age in months",

     main="Boys height: SITAR adjusted")

axis(side=1, at=seq(0, 60, by=12))

axis(side=2, at=seq(50, 120, by=20),las=1)
```

```
mplot(x = ageint_mths, y = height, id = id, ylim=c(50, 110), xlim=c(0,60),data = dhs_g, col = id,
las = 1, axes=FALSE,

      ylab="Height (cm)", xlab="Age in months",main="Girls height: raw")

axis(side=1, at=seq(0, 60, by=12))

axis(side=2, at=seq(50, 110, by=20),las=1)


plot(m6, opt = 'a', col = id, las = 1, ylim=c(50, 110), xlim=c(0,60),axes=FALSE,

     ylab="Height (cm)", xlab="Age in months",

     main="Girls height: SITAR adjusted")

axis(side=1, at=seq(0, 60, by=12))

axis(side=2, at=seq(50, 110, by=20),las=1)


## Figure 3

par(mfrow=c(1,2))

Malawi_ht_boys <- plot(m1, opt = 'd', lty = 1, col="black", axes=FALSE,lwd=0.5,

                     ylab="Height (cm)", xlab="Age in months",

                     main="Boys height (Malawi 2004 survey)")

axis(side=1, at=seq(0, 60, by=12))

axis(side=2, at=seq(40, 120, by=20),las=1)

lines(m1, opt = 'u', subset = id == 27, col="green", lty=1)

lines(m1, opt = 'a', subset = id == 27, col="green", lty=2)

legend('bottomright', c('mean', 'Unadj.MAL.2004', 'Adj.MAL.2004'),

       lty = c(1, 1, 2), col = c("black", "green", "green"), cex = 0.8, inset=0.04)

legend('topleft', c('Size: a = -2.2', 'Intensity: c = -0.05'), cex = 0.8, inset=0.04)
```

```
Egypt_ht_boys <- plot(m1, opt = 'd', lty = 1, col="black", axes=FALSE,lwd=0.5,
            ylab="Height (cm)", xlab="Age in months",
            main="Boys height (Egypt 2014 survey)")
axis(side=1, at=seq(0, 60, by=12))
axis(side=2, at=seq(40, 120, by=20),las=1)
lines(m1, opt = 'u', subset = id == 117, col="green", lty=1)
lines(m1, opt = 'a', subset = id == 117, col="green", lty=2)
legend('bottomright', c('mean', 'Unadj.EGY.2014', 'Adj.EGY.2014'),
    lty = c(1, 1, 2), col = c("black", "green", "green"), cex = 0.8, inset=0.04)
legend('topleft', c('Size: a = 2.4', 'Intensity: c = 0.08'), cex = 0.8,
inset=0.04)
## Supplementary Figure 4
par(mfrow=c(2,2))
par(mar = c(4,4,2,2) + 0.1, cex = 0.8)
plot(height ~ ageint_mths, data = dhs_b, ylim=c(50, 110),las=1,subset = id == 118, main="Boys:
Egypt 2014",
   ylab="Height (cm)", xlab="Age in months")
lines(m3, opt = 'D', subset = id == 118, lty = 1, col="blue")
lines(m3, opt = 'd', lty = 2, col="red")
legend('bottomright', c('Observed', 'Fitted trajectory', 'SITAR average-mean curve'),
    lty = c(NA, 1, 2), pch=c(1,NA,NA), col = c("gray", "blue", "red"), cex = 0.8, inset=0.04)
```


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```
plot(height ~ ageint_mths, data = dhs_g, las=1,ylim=c(50, 110), xlim=c(0,60),subset = id == 104, main="Girls: Peru 2012",
    ylab="Height (cm)", xlab="Age in months",pch=1)
lines(m6, opt = 'D', subset = id == 104, lty = 1, col="blue")
lines(m6, opt = 'd', lty = 2, col="red")
legend('bottomright', c('Observed', 'Fitted trajectory', 'SITAR average-mean curve'),
      lty = c(NA, 1, 2), pch=c(1,NA, NA), col = c("gray", "blue", "red"), cex = 0.8, inset=0.04)

plot(height ~ ageint_mths, data = dhs_b, ylim=c(50, 110),las=1,subset = id == 146, main="Boys: WHO height standards",
    ylab="Height (cm)", xlab="Age in months")
lines(m3, opt = 'D', subset = id == 146, lty = 1, col="blue")
lines(m3, opt = 'd', lty = 2, col="red")
legend('bottomright', c('WHO height standards', 'Fitted trajectory', 'SITAR average-mean curve'),
      lty = c(NA, 1, 2), pch=c(1,NA,NA), col = c("gray", "blue", "red"), cex = 0.8, inset=0.04)

plot(height ~ ageint_mths, data = dhs_g, las=1,ylim=c(50, 110), xlim=c(0,60),subset = id == 146, main="Girls: WHO height standards",
    ylab="Height (cm)", xlab="Age in months",pch=1)
lines(m6, opt = 'D', subset = id == 146, lty = 1, col="blue")
lines(m6, opt = 'd', lty = 2, col="red")
legend('bottomright', c('WHO height standards', 'Fitted trajectory', 'SITAR average-mean curve'),
      lty = c(NA, 1, 2), pch=c(1,NA, NA), col = c("gray", "blue", "red"), cex = 0.8, inset=0.04)
```

```
# WHO CHILD GROWTH STANDARDS DATA

# HEIGHT

#install.packages("remotes") # if "remotes" is not already installed

#remotes::install_github("ki-tools/growthstandards")

who_medht <- data.frame(x = rep(seq(0, 1826.25, length = 61)))


who_medht_boys <- data.frame(who_centile2value(who_medht, p = 50,

                                        x_var = "agedays", y_var = "htcm", sex = "Male", data = NULL)) # Boys

who_medht_girls <- data.frame(who_centile2value(who_medht, p = 50,

                                         x_var = "agedays", y_var = "htcm", sex = "Female", data = NULL)) #
Girls


who_medht <- cbind(who_medht, who_medht_boys,who_medht_girls)

colnames(who_medht) <- c("ageint_mths","WHO_ht_P50_boys","WHO_ht_P50_girls")

head(who_medht)

who_medht$ageint_mths <- (who_medht$ageint_mths)/30.4375 # convert to months


### Figure 4

who_medht<-subset(who_medht, ageint_mths>1)

par(mfrow=c(2,2))

par(mar = c(4,4,1,1) + 0.1, cex = 0.8)

plot(m3, opt = 'D', col = 8, las = 1, axes=FALSE,subset=id<146,

    ylab="Height (cm)", xlab="Age in months",

    main="Boys height")

axis(side=1, at=seq(0, 60, by=12))
```

```
axis(side=2, at=seq(50, 110, by=20),las=1)

lines(m3, opt = 'd', lty = 2, col=4)

lines(m3, opt = 'D', subset=id==146,col="blue",type="l")

#lines(x=who_medht$ageint_mths, y=who_medht$WHO_ht_P50_boys, col='blue', type='l')

legend('topleft', c('fitted', 'mean', 'WHO'),
    lty = c(1, 2, 1), col = c(8, 4, 4), cex = 0.8, inset=0.04)
```

```
plot(m6, opt = 'D', col = 8, las = 1, axes=FALSE,subset=id<146,
    ylab="Height (cm)", xlab="Age in months",
    main="Girls height")
axis(side=1, at=seq(0, 60, by=12))
axis(side=2, at=seq(50, 110, by=20),las=1)
lines(m6, opt = 'd', lty = 2, col=2)
lines(m6, opt = 'D', subset=id==146,col="red",type="l")
#lines(x=who_medht$ageint_mths, y=who_medht$WHO_ht_P50_girls, col='red', type='l')
legend('topleft', c('fitted', 'mean', 'WHO'),
      lty = c(1, 2, 1), col = c(8, 2, 2), cex = 0.8, inset=0.04)

plot(m3, opt = 'd', las = 1, apv = FALSE,col="blue",axes=FALSE,ylim=c(50,110),
    ylab="Height (cm)", xlab="Age in months",
    main="Fitted height for boys and girls")
axis(side=1, at=seq(0, 60, by=12),las=1)
axis(side=2, at=seq(50, 110, by=20),las=1)
lines(m6, opt = 'd', las = 1, apv = FALSE, col="red", lty = 1)
legend("topleft", legend = c("Boys","Girls"), col = c('blue','red'),lwd = c(1, 1))

plot(m3, opt = 'v', las = 1, lty=1, apv = FALSE,col="blue",axes=FALSE,ylim=c(0,8),vlim=c(0,8),
    vlab="Height velocity (cm/month)", xlab="Age in months",
    main="Fitted height velocity for boys and girls")
axis(side=1, at=seq(0, 60, by=12),las=1)
axis(side=2, at=seq(0, 8, by=1),las=1)
```

```
lines(m6, opt = 'v', las = 1, apv = FALSE, col="red", lty = 1)

#points(t(getPeakTrough(dhs_b$ageint_mths, dhs_b$height, peak=FALSE)), pch=25)

legend("topleft", legend = c("Boys","Girls"), col = c('blue','red'),lwd = c(1, 1))



# Random effects for boys

ranef(m3) # SITAR random effects for boys

# Attaching the random effects a and c to the data

random.ht.b<-m3$coefficients$random$id[dhs_b$id,]

colnames(random.ht.b)<-c("a_male_ht", "c_male_ht")

fit_male<-m3$fitted # Renaming the columns in m1$fitted from "fixed" and "id" to "Male fixed effect" and "Male predicted height"

colnames(fit_male)<-c("Male_Fixed_Effect_HT","Male_Predicted_HT")

dhs_b2<-cbind(random.ht.b,fit_male,dhs_b)

dhs_b2 <- dhs_b2[order(dhs_b2$a_male_ht),]


# Calculating a and c relative to the WHO random effects

a_male_ht = dhs_b2$a_male_ht-5.12974361

c_male_ht = dhs_b2$c_male_ht-0.1030932912

dhs_b2 = cbind(a_male_ht, c_male_ht, dhs_b2$mean_LAZ, dhs_b2$meanStunting_weighted, dhs_b2$year, dhs_b2$pickcountry, dhs_b2$id)

colnames(dhs_b2)<-c("male_size_ht", "male_velocity_ht", "mean_HAZ", "Stunting", "year","country","id")

dhs_b2 = as.data.frame(dhs_b2)


# Random effects for girls
```


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```
ranef(m6) # SITAR random effects for girls

# Attaching the random effects a and c to the data

random.ht.g<-m6$coefficients$random$id[dhs_g$id,]

colnames(random.ht.g)<-c("a_female_ht", "c_female_ht")

fit_female<-m6$fitted # Renaming the columns in m1$fitted from "fixed" and "id" to "Male
fixed effect" and "Male predicted height"

colnames(fit_female)<-c("Female_Fixed_Effect_HT","Female_Predicted_HT")

dhs_g2<-cbind(random.ht.g,fit_female,dhs_g)

dhs_g2 <- dhs_g2[order(dhs_g2$a_female_ht),]


# Calculating a and c relative to the WHO random effects

a_female_ht = dhs_g2$a_female_ht-4.909995490

c_female_ht = dhs_g2$c_female_ht-0.1131823325

dhs_g2 = cbind(a_female_ht, c_female_ht, dhs_g2$mean_LAZ,
dhs_g2$meanStunting_weighted, dhs_g2$year,dhs_g2$pickcountry,dhs_g2$id)

colnames(dhs_g2)<-c("female_size_ht", "female_velocity_ht", "mean_HAZ","Stunting",
"year","country","id")

dhs_g2 = as.data.frame(dhs_g2)


# Figure 5

# Remove duplicate rows of the data frame using cyl and vs variables

boys<-distinct(dhs_b2, male_size_ht, .keep_all= TRUE)

girls<-distinct(dhs_g2, female_size_ht, .keep_all= TRUE)

#

malesize = boys$male_size_ht

femalesize = girls$female_size_ht
```

```
maleintensity = boys$male_velocity_ht*100 # expressing intensity as a %

femaleintensity = girls$female_velocity_ht*100 # expressing intensity as a %

par(mfrow=c(2,2))

par(mar = c(4,4,1,1) + 0.1, cex = 0.8)

hist(malesize,main="Size - Boys",xlab="Size relative to the WHO (cm)",

    xlim=c(-8,0), col="blue",las=1,ylim=c(0,30),breaks=25)

hist(femalesize,main="Size - Girls",xlab="Size relative to the WHO (cm)",

    xlim=c(-8,0), col="red",las=1,ylim=c(0,30),breaks=25)

hist(maleintensity,main="Intensity - Boys",xlab="Intensity relative to the WHO (%)",

    xlim=c(-20,5), col="blue",las=1,ylim=c(0,30),breaks=25)

hist(femaleintensity,main="Intensity - Girls",xlab="Intensity relative to the WHO (%)",

    xlim=c(-20,5), col="red",las=1,ylim=c(0,30),breaks=25)


# Stunting for boys

boys = as.data.frame(boys )

Cor_Stunting_b<-cbind(boys$male_size_ht,boys$male_velocity_ht, boys$mean_HAZ,
boys$Stunting)

boys$Stunting = boys$Stunting*100 # converting stunting to a %

Cor_Stunting_b = as.matrix(Cor_Stunting_b )

colnames(Cor_Stunting_b )<-c("Size: Male", "Intensity: Male", "Mean HAZ: Male", "Stunting
(%): Male")


stunting_cor_male = chart.Correlation(Cor_Stunting_b , histogram=FALSE, pch=19)
```

```
# Stunting for girls

girls=as.data.frame(girls)

Cor_Stunting_g<-cbind(girls$female_size_ht,girls$female_velocity_ht,girls$mean_HAZ, girls$Stunting)

girls$Stunting = girls$Stunting*100 # coverting stunting to a %

Cor_Stunting_g = as.matrix(Cor_Stunting_g)

colnames(Cor_Stunting_g)<-c("Size: Female", "Intensity: Female", "Mean HAZ: Female", "Stunting (%): Female")


stunting_cor_female = chart.Correlation(Cor_Stunting_g, histogram=FALSE, pch=19)


# Figure 6A - Boys

# Scatter plot with correlation coefficient

# Male size and intensity

p1 = ggscatter(boys, x = "male_velocity_ht", y = "male_size_ht",

          add = "reg.line",  # Add regressin line

          add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line

          conf.int = TRUE, # Add confidence interval

          ylab="Size parameter (cm)", xlab="Intensity parameter (%)",

          main="Boys",

          cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor

          cor.coeff.args = list(method = "pearson", label.x = -0.2, label.sep = "\n"))
```

```
# Male size and mean HAZ

p3 = ggscatter(boys, x = "mean_HAZ", y = "male_size_ht",

        add = "reg.line",  # Add regressin line

        add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line

        conf.int = TRUE, # Add confidence interval

        ylab="Size (cm)", xlab="Mean HAZ",

        main="Boys", xlim=c(-3,1), ylim=c(-8,0),

        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor

        cor.coeff.args = list(method = "pearson", label.x = -3, label.y = -0.5, label.sep = "\n"))


# Male size and % Stunting

p5 = ggscatter(boys, x = "Stunting", y = "male_size_ht",

        add = "reg.line",  # Add regressin line

        add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line

        conf.int = TRUE, # Add confidence interval

        ylab="Size (cm)", xlab="Stunting (%)",

        main="Boys",xlim=c(0,80), ylim=c(-8,0),

        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor

        cor.coeff.args = list(method = "pearson", label.x = 0, label.y = -0.5, label.sep = "\n"))


# Male intensity and mean HAZ

p7 = ggscatter(boys, x = "mean_HAZ", y = "male_velocity_ht",

        add = "reg.line",  # Add regressin line

        add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line
```

```
            conf.int = TRUE, # Add confidence interval
            ylab="Intensity (%)", xlab="Mean HAZ",
            main="Boys",xlim=c(-3,1), ylim=c(-0.3,0.1),
            cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
            cor.coeff.args = list(method = "pearson", label.x = -3, label.y = 0.05, label.sep = "\n"))

# Male intensity and mean HAZ
p9 = ggscatter(boys, x = "Stunting", y = "male_velocity_ht",
            add = "reg.line",  # Add regressin line
            add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line
            conf.int = TRUE, # Add confidence interval
            ylab="Intensity (%)", xlab="Stunting (%)",
            main="Boys",xlim=c(0,80), ylim=c(-0.3,0.1),
            cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
            cor.coeff.args = list(method = "pearson", label.x = 0, label.y = 0.08, label.sep = "\n"))

plot_grid(p3, p5, p7, p9,labels = "AUTO") # combining plots

# Figure 6B - Girls
# Scatter plot with correlation coefficient
# Female size and intensity
p2 = ggscatter(girls, x = "female_velocity_ht", y = "female_size_ht",
            add = "reg.line",  # Add regressin line
            add.params = list(color = "red", fill = "lightgray"), # Customize reg. line
```


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```
            conf.int = TRUE, # Add confidence interval
            ylab="Size parameter (cm)", xlab="Intensity parameter (%)",
            main="Girls",
            cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
            cor.coeff.args = list(method = "pearson", label.x = -0.2, label.sep = "\n"))

# Female size and mean HAZ
p4 = ggscatter(girls, x = "mean_HAZ", y = "female_size_ht",
            add = "reg.line",  # Add regressin line
            add.params = list(color = "red", fill = "lightgray"), # Customize reg. line
            conf.int = TRUE, # Add confidence interval
            ylab="Size (cm)", xlab="Mean HAZ",
            main="Girls", xlim=c(-3,1), ylim=c(-8,0),
            cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
            cor.coeff.args = list(method = "pearson", label.x = -3, label.y = -0.5, label.sep = "\n"))

# Female size and % Stunting
p6 = ggscatter(girls, x = "Stunting", y = "female_size_ht",
            add = "reg.line",  # Add regressin line
            add.params = list(color = "red", fill = "lightgray"), # Customize reg. line
            conf.int = TRUE, # Add confidence interval
            ylab="Size (cm)", xlab="Stunting (%)",
            main="Girls",xlim=c(0,80), ylim=c(-8,0),
            cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
```

```
        cor.coeff.args = list(method = "pearson", label.x = 0, label.y = -0.45, label.sep = "\n"))

# Female intensity and mean HAZ
p8 = ggscatter(girls, x = "mean_HAZ", y = "female_velocity_ht",
        add = "reg.line",  # Add regressin line
        add.params = list(color = "red", fill = "lightgray"), # Customize reg. line
        conf.int = TRUE, # Add confidence interval
        ylab="Intensity (%)", xlab="Mean HAZ",
        main="Girls",xlim=c(-3,1), ylim=c(-0.3,0.1),
        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
        cor.coeff.args = list(method = "pearson", label.x = -3, label.y = 0.05, label.sep = "\n"))

# Female intensity and mean HAZ
p10 = ggscatter(girls, x = "Stunting", y = "female_velocity_ht",
        add = "reg.line",  # Add regressin line
        add.params = list(color = "red", fill = "lightgray"), # Customize reg. line
        conf.int = TRUE, # Add confidence interval
        ylab="Intensity (%)", xlab="Stunting (%)",
        main="Girls",xlim=c(0,80), ylim=c(-0.3,0.1),
        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
        cor.coeff.args = list(method = "pearson", label.x = 0, label.y = 0.08, label.sep = "\n"))

plot_grid(p4, p6, p8, p10,labels = "AUTO") # combining plots
```

```
# Male intensity and male size
boys$male_velocity_ht = boys$male_velocity_ht*100
girls$female_velocity_ht = girls$female_velocity_ht*100

p11 = ggscatter(boys, y = "male_size_ht", x = "male_velocity_ht",
        add = "reg.line",  # Add regressin line
        add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line
        conf.int = TRUE, # Add confidence interval
        xlab="Intensity (%)", ylab="Size (cm)",
        main="Boys",xlim=c(-20,5), ylim=c(-8,0),
        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
        cor.coeff.args = list(method = "pearson", label.x = 0, label.y = 0.08, label.sep = "\n"))

# Male intensity and male size
p12 = ggscatter(girls, y = "female_size_ht", x = "female_velocity_ht",
        add = "reg.line",  # Add regressin line
        add.params = list(color = "blue", fill = "lightgray"), # Customize reg. line
        conf.int = TRUE, # Add confidence interval
        xlab="Intensity (%)", ylab="Size (cm)",
        main="Girls",xlim=c(-20,5), ylim=c(-8,0),
        cor.coef = TRUE, # Add correlation coefficient. see ?stat_cor
        cor.coeff.args = list(method = "pearson", label.x = 0, label.y = 0.08, label.sep = "\n"))

plot_grid(p11, p12,labels = "AUTO") # Better for combining plots
```

```
## Figure 7A

## add extra space to right margin of plot within frame

boys$year <- boys$year+1999

girls$year <- girls$year+1999


par(mfrow=c(2,2))

par(mar=c(5, 4, 4, 6) + 0.1)

## Plot first set of data and draw its axis

plot(male_size_ht ~year, data=boys, pch=16, axes=FALSE, ylim=c(-8,0),

    xlim=c(2000,2020), xlab="", ylab="", subset = country == 50,

    main="Boys: Peru",col="black")

axis(2, ylim=c(-8,0),col="black",las=1)  ## las=1 makes horizontal labels

axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels

mtext("Size (cm)",side=2,line=2.5)

box()

## Allow a second plot on the same graph

par(new=TRUE)

## Plot the second plot and put axis scale on right

plot(mean_HAZ ~ year, pch=1, data=boys,  xlab="", ylab="",

    ylim=c(-4,4), xlim=c(2000,2020),

    axes=FALSE, col="black",subset = country == 50)

## a little farther out (line=4) to make room for labels
```

```
mtext("Mean HAZ",side=4,col="black",line=4)

axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)


## Draw the time axis

mtext("Survey year",side=1,col="black",line=2.5)

box()

## Add Legend

legend("topleft",legend=c("Size parameter","Mean HAZ"),

      text.col=c("black","black"),pch=c(16,1),col=c("black","black"))


par(mar = c(5,4,4,6) + 0.1, cex = 0.8)

## Plot first set of data and draw its axis

plot(male_size_ht ~year, data=boys, pch=16, axes=FALSE, ylim=c(-8,0),

    xlim=c(2000,2020), xlab="", ylab="", subset = country == 53,

    main="Boys: Senegal",col="black")

axis(2, ylim=c(-8,0),col="black",las=1)  ## las=1 makes horizontal labels

axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels

mtext("Size (cm)",side=2,line=2.5)

box()

## Allow a second plot on the same graph

par(new=TRUE)

## Plot the second plot and put axis scale on right

plot(mean_HAZ ~ year, pch=1, data=boys,  xlab="", ylab="",

    ylim=c(-4,4), xlim=c(2000,2020),
```


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```
    axes=FALSE, col="black",subset = country == 53)
## a little farther out (line=4) to make room for labels
mtext("Mean HAZ",side=4,col="black",line=4)
axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)

## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
#box()
## Add Legend
legend("topleft",legend=c("Size parameter","Mean HAZ"),
     text.col=c("black","black"),pch=c(16,1),col=c("black","black"))

par(mar = c(5,4,4,6) + 0.1, cex = 0.8)
## Plot first set of data and draw its axis
plot(female_size_ht ~year, data=girls, pch=16, axes=FALSE, ylim=c(-8,0),
    xlim=c(2000,2020), xlab="", ylab="", subset = country == 19,
    main="Girls: Egypt",col="black")
axis(2, ylim=c(-8,0),col="black",las=1)  ## las=1 makes horizontal labels
axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels
mtext("Size (cm)",side=2,line=2.5)
box()
## Allow a second plot on the same graph
par(new=TRUE)
## Plot the second plot and put axis scale on right
```

```
plot(mean_HAZ ~ year, pch=1, data=girls,  xlab="", ylab="",
    ylim=c(-4,4), xlim=c(2000,2020),
    axes=FALSE, col="black",subset = country == 19)
## a little farther out (line=4) to make room for labels
mtext("Mean HAZ",side=4,col="black",line=4)
axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)

## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
box()
## Add Legend
legend("topleft",legend=c("Size parameter","Mean HAZ"),
      text.col=c("black","black"),pch=c(16,1),col=c("black","black"))

par(mar=c(5, 4, 4, 6) + 0.1)
## Plot first set of data and draw its axis
plot(female_size_ht ~year, data=girls, pch=16, axes=FALSE, ylim=c(-8,0),
    xlim=c(2000,2020), xlab="", ylab="", subset = country == 45,
    main="Girls: Nepal",col="black")
axis(2, ylim=c(-8,0),col="black",las=1)  ## las=1 makes horizontal labels
axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels
mtext("Size (cm)",side=2,line=2.5)
box()
## Allow a second plot on the same graph
```

```
par(new=TRUE)

## Plot the second plot and put axis scale on right

plot(mean_HAZ ~ year, pch=1, data=girls,  xlab="", ylab="",

    ylim=c(-4,4), xlim=c(2000,2020),

    axes=FALSE, col="black",subset = country == 45)

## a little farther out (line=4) to make room for labels

mtext("Mean HAZ",side=4,col="black",line=4)

axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)


## Draw the time axis

mtext("Survey year",side=1,col="black",line=2.5)

box()

## Add Legend

legend("topleft",legend=c("Size parameter","Mean HAZ"),

      text.col=c("black","black"),pch=c(16,1),col=c("black","black"))


# Intensity


## Figure 7B


## add extra space to right margin of plot within frame


par(mfrow=c(2,2))

par(mar=c(5, 4, 4, 6) + 0.1)
```


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```
## Plot first set of data and draw its axis
plot(male_velocity_ht ~year, data=boys, pch=16, axes=FALSE, ylim=c(-10,0),
    xlim=c(2000,2020), xlab="", ylab="", subset = country == 50,
    main="Boys: Peru",col="black")
axis(2, ylim=c(-10,0),col="black",las=1)  ## las=1 makes horizontal labels
axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels
mtext("Intensity (%)",side=2,line=2.5)
box()
## Allow a second plot on the same graph
par(new=TRUE)
## Plot the second plot and put axis scale on right
plot(mean_HAZ ~ year, pch=1, data=boys,  xlab="", ylab="",
    ylim=c(-4,4), xlim=c(2000,2020),
    axes=FALSE, col="black",subset = country == 50)
## a little farther out (line=4) to make room for labels
mtext("Mean HAZ",side=4,col="black",line=4)
axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)

## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
box()
## Add Legend
legend("topleft",legend=c("Intensity parameter","Mean HAZ"),
     text.col=c("black","black"),pch=c(16,1),col=c("black","black"))
```

```
par(mar = c(5,4,4,6) + 0.1, cex = 0.8)
## Plot first set of data and draw its axis
plot(male_size_ht ~year, data=boys, pch=16, axes=FALSE, ylim=c(-10,0),
    xlim=c(2000,2020), xlab="", ylab="", subset = country == 53,
    main="Boys: Senegal",col="black")
axis(2, ylim=c(-10,0),col="black",las=1)  ## las=1 makes horizontal labels
axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels
mtext("Intensity (%)",side=2,line=2.5)
box()
## Allow a second plot on the same graph
par(new=TRUE)
## Plot the second plot and put axis scale on right
plot(mean_HAZ ~ year, pch=1, data=boys,  xlab="", ylab="",
    ylim=c(-4,4), xlim=c(2000,2020),
    axes=FALSE, col="black",subset = country == 53)
## a little farther out (line=4) to make room for labels
mtext("Mean HAZ",side=4,col="black",line=4)
axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)


## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
#box()
## Add Legend
```

```
legend("topleft",legend=c("Intensity parameter","Mean HAZ"),
      text.col=c("black","black"),pch=c(16,1),col=c("black","black"))


par(mar = c(5,4,4,6) + 0.1, cex = 0.8)
## Plot first set of data and draw its axis
plot(female_size_ht ~year, data=girls, pch=16, axes=FALSE, ylim=c(-10,0),
    xlim=c(2000,2020), xlab="", ylab="", subset = country == 19,
    main="Girls: Egypt",col="black")
axis(2, ylim=c(-10,0),col="black",las=1)  ## las=1 makes horizontal labels
axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels
mtext("Intensity (%)",side=2,line=2.5)
box()
## Allow a second plot on the same graph
par(new=TRUE)
## Plot the second plot and put axis scale on right
plot(mean_HAZ ~ year, pch=1, data=girls,  xlab="", ylab="",
    ylim=c(-4,4), xlim=c(2000,2020),
    axes=FALSE, col="black",subset = country == 19)
## a little farther out (line=4) to make room for labels
mtext("Mean HAZ",side=4,col="black",line=4)
axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)


## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
```

```
box()

## Add Legend

legend("topleft",legend=c("Intensity parameter","Mean HAZ"),

      text.col=c("black","black"),pch=c(16,1),col=c("black","black"))


par(mar=c(5, 4, 4, 6) + 0.1)

## Plot first set of data and draw its axis

plot(female_size_ht ~year, data=girls, pch=16, axes=FALSE, ylim=c(-10,0),

    xlim=c(2000,2020), xlab="", ylab="", subset = country == 45,

    main="Girls: Nepal",col="black")

axis(2, ylim=c(-10,0),col="black",las=1)  ## las=1 makes horizontal labels

axis(1, xlim=c(2000,2020),col="black",las=1)  ## las=1 makes horizontal labels

mtext("Intensity (%)",side=2,line=2.5)

box()

## Allow a second plot on the same graph

par(new=TRUE)

## Plot the second plot and put axis scale on right

plot(mean_HAZ ~ year, pch=1, data=girls,  xlab="", ylab="",

    ylim=c(-4,4), xlim=c(2000,2020),

    axes=FALSE, col="black",subset = country == 45)

## a little farther out (line=4) to make room for labels

mtext("Mean HAZ",side=4,col="black",line=4)

axis(4, ylim=c(-4,4), col="black",col.axis="black",las=1)
```

```
## Draw the time axis
mtext("Survey year",side=1,col="black",line=2.5)
box()
## Add Legend
legend("topleft",legend=c("Intensity parameter","Mean HAZ"),
    text.col=c("black","black"),pch=c(16,1),col=c("black","black"))


# Effect of size on SITAR parameters
## BOYS
size_birth = subset(dhs_b, ageint_mths==2)
size_birth = merge(size_birth, boys, by="id")
cor(size_birth$height,size_birth$male_size_ht) # 0.41
cor(size_birth$height,size_birth$male_velocity_ht) # 0.14
cor(size_birth$male_size_ht,size_birth$male_velocity_ht) # 0.91
lm1 <- lm(size_birth$male_size_ht ~ size_birth$height, data=size_birth)
print(lm1)
summary(lm1)
AIC(lm1)
confint(lm1)

lm2 <- lm(size_birth$male_velocity_ht ~ size_birth$height, data=size_birth)
print(lm2)
```

```
summary(lm2)

AIC(lm2)

confint(lm2)


lm3 <- lm(size_birth$male_size_ht ~ size_birth$male_velocity_ht, data=size_birth)

print(lm3)

summary(lm3)

AIC(lm3)

confint(lm3)


lm4 <- lm(size_birth$male_size_ht ~ size_birth$height + size_birth$male_velocity_ht,
data=size_birth)

print(lm4)

summary(lm4)

confint(lm4)

BIC(lm1, lm2, lm3, lm4) # BIC for each model


## GIRLS

size_birth = subset(dhs_g, ageint_mths==2)

size_birth = merge(size_birth, girls, by="id")

cor(size_birth$height,size_birth$female_size_ht) # 0.43

cor(size_birth$height,size_birth$female_velocity_ht) # 0.14

cor(size_birth$female_size_ht,size_birth$female_velocity_ht) # 0.89

lf1 <- lm(size_birth$female_size_ht ~ size_birth$height, data=size_birth)

print(lf1)
```


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```
summary(lf1)

AIC(lf1)

confint(lf1)


lf2 <- lm(size_birth$female_velocity_ht ~ size_birth$height, data=size_birth)

print(lf2)

summary(lf2)

AIC(lf2)

confint(lf2)


lf3 <- lm(size_birth$female_size_ht ~ size_birth$female_velocity_ht, data=size_birth)

print(lf3)

summary(lf3)

AIC(lf3)

confint(lf3)


lf4 <- lm(size_birth$female_size_ht ~ size_birth$height + size_birth$female_velocity_ht,
data=size_birth)

print(lf4)

summary(lf4)

confint(lf4)

BIC(lf1, lf2, lf3, lf4) # BIC for each model
```


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Supplementary File 3: Summary of 145 Demographic Health Surveys used for analyses

country	year	Total sample	% Boys	Median age in months (IQR)
Albania	2009	1,473	49.8%	33.5 (18.4 - 48.2)
Albania	2017	2,610	51.0%	29.7 (14.7 - 44.9)
Angola	2015	7,513	49.9%	28.9 (13.6 - 43.6)
Armenia	2005	1,290	54.4%	27.4 (13.9 - 42.6)
Armenia	2010	1,390	52.2%	27.7 (14.2 - 43)
Armenia	2016	1,593	52.9%	29 (15.1 - 44.4)
Azerbaijan	2006	2,049	53.4%	27.1 (13.4 - 42.9)
Bangladesh	2004	6,102	50.6%	28.9 (14.4 - 43.9)
Bangladesh	2007	5,473	49.6%	29.3 (15.2 - 44.1)
Bangladesh	2011	7,920	50.6%	31.8 (14.8 - 45.9)
Bangladesh	2014	7,235	52.0%	29.5 (14.3 - 44.7)
Benin	2001	4,098	49.8%	25.8 (11.5 - 40.9)
Benin	2006	13,520	50.0%	27.8 (12.8 - 42.4)
Benin	2012	9,367	50.0%	30.6 (15.6 - 45)
Bolivia	2003	9,823	51.4%	31.3 (15.6 - 46.1)
Bolivia	2008	8,395	50.7%	29.8 (14.9 - 44.9)
Burkina Faso	2003	8,882	51.1%	28.5 (12.7 - 43.2)
Burkina Faso	2010	6,960	51.0%	28.6 (13.9 - 43.7)
Burundi	2010	3,612	51.2%	28.2 (14.5 - 43.4)
Burundi	2016	6,358	50.3%	29.9 (14.6 - 45.5)
Cambodia	2000	3,753	51.4%	31 (14 - 45.5)
Cambodia	2005	3,853	48.4%	29.6 (15 - 44.6)
Cambodia	2010	4,103	51.5%	30.1 (15.1 - 45.2)
Cambodia	2014	4,938	50.9%	29.2 (15.2 - 44.2)
Cameroon	2004	3,756	50.0%	27.5 (13.5 - 44.6)
Cameroon	2011	5,882	48.8%	28.1 (13.5 - 43.4)
Chad	2015	10,760	50.0%	30.6 (13.9 - 45.3)
Colombia	2010	17,749	51.4%	30.6 (15.4 - 45.2)
Comoros	2012	2,883	50.1%	29.3 (14.4 - 43.4)
Congo Brazzaville	2005	4,418	50.8%	27.6 (13.3 - 42.4)
Congo Brazzaville	2011	4,965	49.6%	28.3 (13.3 - 42)
Congo, DRC	2007	3,717	48.8%	29.1 (14.7 - 44.7)
Congo, DRC	2013	9,031	50.2%	29.2 (13.7 - 44.2)
Ivory coast	2012	3,788	49.0%	28.2 (13.3 - 42.6)

Dominican Republic	2002	11,017	50.7%	29.9 (15.7 - 44.9)
Dominican Republic	2007	11,084	52.1%	31.5 (16.5 - 45.9)
Dominican Republic	2013	3,678	51.1%	31.1 (15.7 - 45.8)
Egypt	2000	10,692	51.5%	28.5 (13.8 - 43.2)
Egypt	2003	6,213	52.1%	29 (14.7 - 44.3)
Egypt	2005	12,907	50.6%	29.8 (15 - 44.5)
Egypt	2008	10,112	50.5%	27.7 (13.3 - 43.5)
Egypt	2014	14,717	52.2%	28.8 (14.3 - 43.4)
Eritrea	2002	5,627	50.9%	30.6 (13.6 - 46.1)
Ethiopia	2000	9,326	50.2%	29.8 (14.7 - 43.9)
Ethiopia	2005	4,221	50.1%	31.1 (14.7 - 45.4)
Ethiopia	2011	10,400	51.2%	31.5 (14.4 - 45.1)
Ethiopia	2016	9,471	51.1%	29.7 (14 - 45.5)
Gabon	2012	4,155	51.2%	29.5 (13.1 - 43.3)
Gambia	2013	3,598	51.2%	27.5 (12.7 - 42.2)
Ghana	2008	2,714	51.1%	29.9 (15.1 - 45.4)
Ghana	2014	3,049	52.5%	29.3 (14.5 - 43.5)
Guatemala	2015	12,286	51.7%	29.9 (14.8 - 44.6)
Guinea	2012	3,572	51.5%	28.9 (14.1 - 43.4)
Guyana	2009	1,823	49.8%	29.7 (15.9 - 44.9)
Haiti	2000	6,436	49.5%	29.3 (15.5 - 43.8)
Haiti	2006	2,974	48.8%	29.7 (14.7 - 43.7)
Haiti	2012	4,742	51.6%	27.8 (13.5 - 43.5)
Haiti	2017	6,769	49.8%	30.9 (15.4 - 46.1)
Honduras	2006	10,275	51.1%	31.5 (17 - 46)
Honduras	2012	10,943	52.3%	28.6 (14.2 - 44)
India	2006	43,728	52.3%	30.1 (15.3 - 44.8)
India	2015	239,588	52.0%	30.2 (15.3 - 44.6)
Jordan	2002	4,990	50.1%	28.7 (13.8 - 44.3)
Jordan	2007	4,648	50.0%	30.1 (15.4 - 45.3)
Jordan	2009	4,444	51.9%	28 (14.4 - 43)
Jordan	2012	6,412	51.5%	31.3 (16 - 45.2)
Kenya	2003	5,157	50.3%	28.6 (13.2 - 43.7)
Kenya	2009	5,684	51.1%	29.5 (14.9 - 44.5)
Kenya	2014	20,668	50.9%	30 (15 - 44.5)
Kyrgyzstan	2012	4,618	51.7%	27.7 (13.8 - 42.9)
Lesotho	2009	2,235	49.5%	29.5 (14.7 - 45.4)
Lesotho	2014	1,907	48.1%	30.8 (15.4 - 44.7)
Liberia	2007	5,329	51.8%	30.2 (14.8 - 45)

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Liberia	2013	3,867	53.8%	29.9 (14.2 - 45.1)
Madagascar	2004	5,043	48.9%	28.6 (13.8 - 44.2)
Madagascar	2009	5,841	50.0%	31.2 (15.3 - 45.8)
Malawi	2000	10,226	49.2%	27.5 (12.9 - 42.4)
Malawi	2004	9,098	49.4%	27.9 (13.4 - 43.8)
Malawi	2010	5,007	48.6%	29.3 (15.4 - 44.3)
Malawi	2015	5,686	48.6%	30.8 (15.3 - 45.4)
Maldives	2009	2,636	50.6%	28.7 (13.3 - 44)
Mali	2001	10,427	50.6%	27.5 (12 - 43.3)
Mali	2006	12,062	50.6%	27.2 (13 - 42.5)
Mali	2012	4,951	51.4%	31.6 (16.9 - 45.2)
Moldova	2005	1,506	50.9%	29.6 (15.3 - 43.9)
Morocco	2003	5,694	49.7%	30 (14.9 - 44.9)
Mozambique	2003	9,103	49.3%	28.5 (13.3 - 43.2)
Mozambique	2011	10,411	49.9%	28.3 (13.3 - 43.2)
Myanmar	2016	4,648	51.7%	30 (15 - 45)
Namibia	2000	4,023	49.7%	28.6 (14.2 - 44.2)
Namibia	2007	5,167	49.9%	29 (14 - 43.7)
Namibia	2013	2,617	49.2%	28.7 (14.6 - 44.1)
Nepal	2001	6,389	49.0%	29.6 (14.6 - 44.3)
Nepal	2006	5,450	51.5%	30.8 (15.9 - 45.3)
Nepal	2011	2,441	51.3%	30.3 (15 - 44.1)
Nepal	2016	2,446	52.0%	29.9 (15.7 - 44.9)
Nicaragua	2001	6,650	51.0%	29.8 (15.7 - 44.4)
Niger	2006	4,043	51.5%	27.6 (12.6 - 42.9)
Niger	2012	5,310	50.2%	28.4 (13.1 - 43.5)
Nigeria	2003	4,824	49.9%	26.7 (11.9 - 41.9)
Nigeria	2008	22,394	50.1%	28.6 (13.3 - 43.2)
Nigeria	2013	27,358	50.1%	29 (13.6 - 44.3)
Pakistan	2012	3,316	50.1%	29.5 (14.1 - 44.7)
Pakistan	2018	4,211	51.2%	29 (14.4 - 43.7)
Peru	2005	2,454	51.1%	29.4 (14.3 - 45.1)
Peru	2008	8,554	50.2%	31 (16 - 45.6)
Peru	2009	9,814	51.4%	30.8 (14.6 - 46.1)
Peru	2010	9,249	50.4%	30.2 (15.7 - 45.5)
Peru	2011	9,193	50.8%	30.2 (15.6 - 44.8)
Peru	2012	9,675	50.9%	30.8 (15.5 - 45.1)
Rwanda	2000	6,681	49.6%	28.6 (12 - 44.6)
Rwanda	2005	3,936	49.0%	27.9 (13.4 - 41.8)

Rwanda	2010	4,368	50.2%	31.1 (16.3 - 45.3)
Rwanda	2015	3,810	50.5%	29.3 (14.3 - 43)
Sao Tome and Principe	2008	1,831	49.9%	30 (16.3 - 43.3)
Senegal	2005	3,179	51.1%	27.6 (13.4 - 42.3)
Senegal	2010	4,005	51.5%	27.9 (13.5 - 42.8)
Senegal	2013	6,550	50.0%	28.7 (13.9 - 43.1)
Senegal	2014	6,762	51.1%	29.4 (15.4 - 44.4)
Senegal	2015	6,885	50.2%	29.9 (15.1 - 44.4)
Senegal	2016	6,699	51.3%	30.5 (15.2 - 44.5)
Senegal	2017	11,919	51.3%	30.4 (15.3 - 45.2)
Sierra Leone	2008	2,794	48.8%	28.6 (14.1 - 44.3)
Sierra Leone	2013	5,367	48.6%	30.8 (15.3 - 44.5)
South Africa	2016	1,468	50.8%	31.3 (16 - 46.1)
Swaziland	2006	2,815	49.5%	30.1 (15 - 45.3)
Tajikistan	2012	4,781	50.9%	27.7 (14 - 42.4)
Tajikistan	2017	6,038	50.3%	29.4 (15.3 - 44.6)
Tanzania	2004	7,938	49.9%	28 (13.6 - 43.5)
Tanzania	2010	7,632	49.5%	28.9 (14.2 - 44.3)
Tanzania	2015	10,184	50.5%	29 (14.8 - 44.4)
Timor-Leste	2009	8,452	50.5%	31.2 (16.4 - 44.8)
Timor-Leste	2016	6,661	51.4%	31.2 (16.6 - 45.1)
Togo	2014	3,535	50.4%	29.6 (14.9 - 44.4)
Uganda	2000	5,693	49.8%	27.1 (13.8 - 43)
Uganda	2006	2,661	50.6%	28.6 (13.8 - 43.4)
Uganda	2011	2,360	49.7%	28.6 (14 - 43.6)
Uganda	2016	5,160	50.2%	29.9 (15.6 - 44.9)
Yemen	2013	14,344	50.9%	27.9 (13.6 - 43.5)
Zambia	2002	5,985	49.8%	28 (13.8 - 43.5)
Zambia	2007	5,715	49.4%	28.3 (14.3 - 43.7)
Zambia	2013	12,627	50.3%	30.3 (15.4 - 45.4)
Zimbabwe	2005	5,061	50.0%	31 (15.3 - 45.8)
Zimbabwe	2010	5,359	49.5%	27.5 (12.3 - 42.3)
Zimbabwe	2015	6,084	49.6%	31.8 (16.7 - 46.3)
Total		**1,208,483**	**50.9%**	**29.6 (14.6 - 44.4)**

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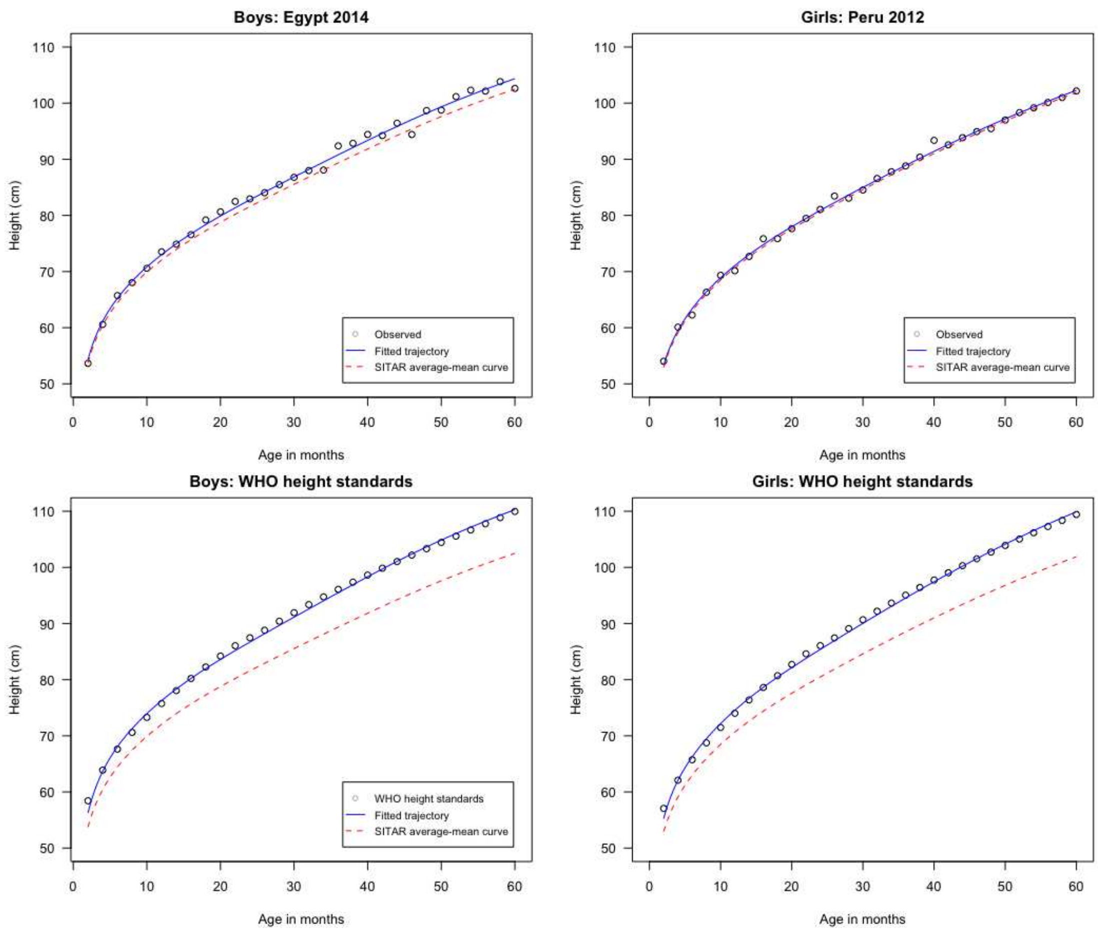
Supplementary File 4: Goodness of fit plots after SITAR modelling. For illustration, we show crude height data for boy's height in Egypt in 2014 (open circles, top-left panel), girls in Peru in 2012 (open circles, top-right panel), WHO child height standards for boys (open circles, bottom-left panel), and WHO child height standards for girls (open circles, bottom-right panel). The corresponding SITAR fitted growth curves are shown in solid blue line and the fitted SITAR population-mean curves are shown by red dotted line



Supplementary File 5: Table of the SITAR random effects for size and intensity parameters with and without inclusion of the mean height of the WHO child growth standards in the multi-country dataset for boys and girls

		Without WHO data included				With WHO data included			
		Female		Male		Female		Male	
Country	Survey year	Size	Intensity	Size	Intensity	Size	Intensity	Size	Intensity
Albania	2009	1.811	0.076	2.216	0.091	1.780	0.075	2.184	0.090
Albania	2017	2.739	0.086	3.355	0.085	2.713	0.085	3.332	0.083
Angola	2015	-0.507	0.020	-0.504	-0.010	-0.545	0.019	-0.543	-0.011
Armenia	2005	2.605	0.125	3.344	0.100	2.575	0.124	3.319	0.099
Armenia	2010	1.687	0.034	1.559	0.057	1.659	0.033	1.526	0.056
Armenia	2016	3.965	0.129	3.753	0.122	3.942	0.128	3.728	0.120
Azerbaijan	2006	0.229	-0.039	0.290	-0.008	0.199	-0.040	0.257	-0.009
Bangladesh	2004	-2.098	-0.050	-1.758	-0.044	-2.139	-0.050	-1.802	-0.044
Bangladesh	2007	-1.420	-0.046	-0.900	-0.034	-1.459	-0.046	-0.939	-0.034
Bangladesh	2011	-1.152	-0.033	-0.766	-0.009	-1.190	-0.034	-0.807	-0.010
Bangladesh	2014	-0.794	-0.033	-0.355	-0.007	-0.830	-0.034	-0.393	-0.008
Benin	2001	-0.417	-0.025	-0.366	-0.038	-0.452	-0.026	-0.400	-0.039
Benin	2006	-1.649	-0.053	-1.904	-0.049	-1.688	-0.053	-1.949	-0.049
Benin	2012	-2.242	-0.083	-2.648	-0.062	-2.282	-0.083	-2.697	-0.062
Bolivia	2003	-0.201	-0.005	0.042	0.008	-0.237	-0.006	0.004	0.007
Bolivia	2008	0.289	0.002	0.588	0.015	0.255	0.002	0.554	0.015
Burkina Faso	2003	-1.123	-0.072	-1.420	-0.074	-1.158	-0.073	-1.457	-0.074
Burkina Faso	2010	-0.281	-0.012	-0.270	-0.006	-0.316	-0.012	-0.308	-0.007
Burundi	2010	-2.378	-0.055	-2.583	-0.071	-2.421	-0.055	-2.630	-0.071
Burundi	2016	-2.309	-0.049	-2.473	-0.061	-2.352	-0.050	-2.520	-0.061
Cambodia	2000	-1.781	-0.070	-1.424	-0.055	-1.820	-0.071	-1.464	-0.055
Cambodia	2005	-1.301	-0.044	-1.182	-0.051	-1.339	-0.045	-1.221	-0.051
Cambodia	2010	-1.052	-0.053	-0.667	-0.054	-1.089	-0.053	-0.702	-0.055
Cambodia	2014	-0.257	-0.025	-0.018	-0.011	-0.292	-0.026	-0.053	-0.012
Cameroon	2004	-0.258	0.004	-0.012	0.012	-0.294	0.003	-0.050	0.011
Cameroon	2011	0.187	-0.018	0.092	-0.013	0.155	-0.019	0.058	-0.014
Chad	2015	-0.551	-0.049	-0.665	-0.066	-0.585	-0.050	-0.697	-0.067
Colombia	2010	1.650	0.076	1.876	0.068	1.618	0.075	1.845	0.067

		Without WHO data included				With WHO data included			
		Female		Male		Female		Male	
Country	**Survey year**	**Size**	**Intensity**	**Size**	**Intensity**	**Size**	**Intensity**	**Size**	**Intensity**
Comoros	2012	0.362	0.007	0.162	0.018	0.329	0.006	0.125	0.018
Congo Brazzaville	2005	0.943	0.000	0.482	0.009	0.914	-0.001	0.448	0.008
Congo Brazzaville	2011	0.808	0.040	1.101	0.041	0.774	0.039	1.068	0.040
Congo, DRC	2007	-1.499	-0.087	-2.667	-0.099	-1.535	-0.088	-2.710	-0.100
Congo, DRC	2013	-0.839	-0.077	-1.042	-0.065	-0.873	-0.078	-1.078	-0.066
Ivory Coast	2012	0.555	-0.007	0.436	-0.006	0.524	-0.008	0.404	-0.008
Dominican Republic	2002	2.800	0.101	2.909	0.101	2.773	0.100	2.880	0.100
Dominican Republic	2007	3.013	0.091	3.134	0.094	2.987	0.089	3.109	0.093
Dominican Republic	2013	3.150	0.124	3.169	0.120	3.122	0.123	3.140	0.118
Egypt	2000	0.828	0.069	0.798	0.061	0.793	0.069	0.759	0.060
Egypt	2003	1.035	0.070	0.778	0.090	1.001	0.069	0.734	0.089
Egypt	2005	1.380	0.067	1.333	0.075	1.348	0.066	1.296	0.074
Egypt	2008	0.918	0.018	0.567	0.017	0.887	0.017	0.533	0.016
Egypt	2014	2.738	0.063	2.828	0.077	2.713	0.062	2.803	0.076
Eritrea	2002	-1.359	-0.049	-1.145	-0.052	-1.397	-0.050	-1.183	-0.052
Ethiopia	2000	-2.820	-0.100	-2.707	-0.083	-2.861	-0.101	-2.753	-0.083
Ethiopia	2005	-2.105	-0.083	-2.157	-0.088	-2.145	-0.083	-2.198	-0.088
Ethiopia	2011	-1.047	-0.060	-1.058	-0.060	-1.083	-0.061	-1.094	-0.061
Ethiopia	2016	-0.329	-0.014	-0.469	-0.038	-0.364	-0.015	-0.504	-0.039
Gabon	2012	1.850	0.072	1.777	0.068	1.820	0.071	1.745	0.067
Gambia	2013	1.257	0.031	1.761	0.053	1.227	0.030	1.731	0.052
Ghana	2008	0.473	-0.011	0.623	-0.006	0.441	-0.012	0.592	-0.008
Ghana	2014	1.218	0.033	1.393	0.033	1.187	0.032	1.362	0.032
Guatemala	2015	-1.621	-0.005	-1.305	0.008	-1.664	-0.005	-1.353	0.008
Guinea	2012	0.695	-0.005	0.830	-0.015	0.665	-0.007	0.802	-0.016
Guyana	2009	0.869	0.101	0.941	0.112	0.832	0.100	0.895	0.112
Haiti	2000	0.818	0.018	0.336	0.012	0.787	0.017	0.300	0.011
Haiti	2006	0.159	0.034	0.029	0.009	0.123	0.034	-0.008	0.008
Haiti	2012	1.073	0.038	1.289	0.029	1.042	0.037	1.258	0.027
Haiti	2017	1.324	0.059	1.190	0.053	1.292	0.058	1.156	0.052

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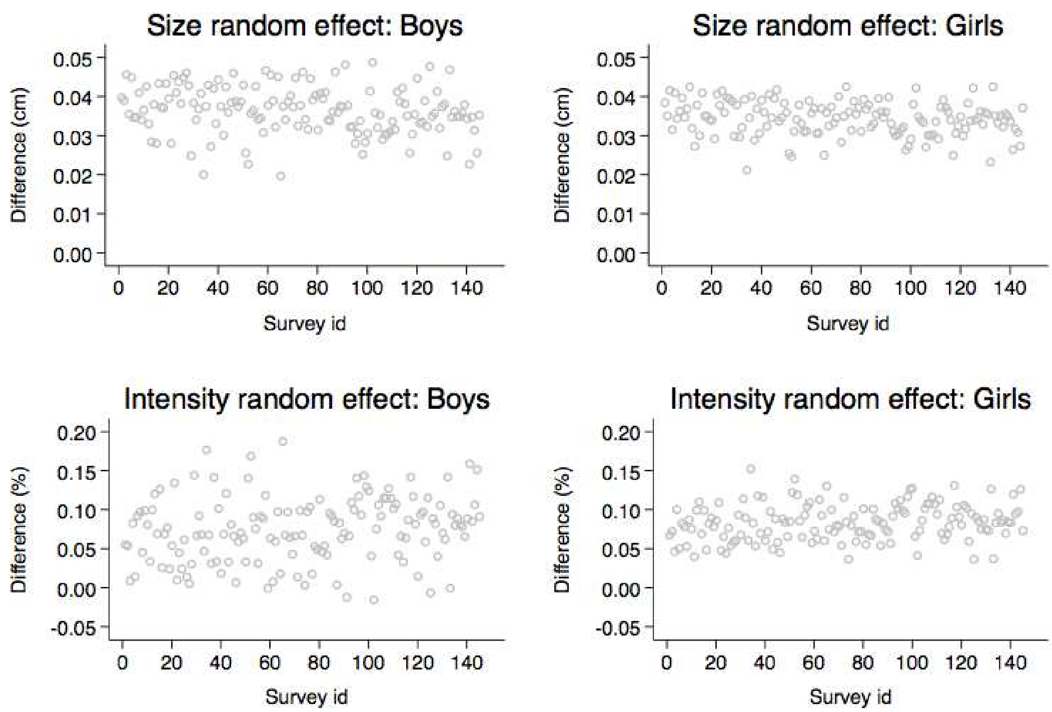
		Without WHO data included				With WHO data included			
		Female		Male		Female		Male	
Country	Survey year	Size	Intensity	Size	Intensity	Size	Intensity	Size	Intensity
Honduras	2006	0.347	-0.005	0.589	-0.014	0.315	-0.006	0.559	-0.015
Honduras	2012	0.739	0.021	0.841	0.027	0.707	0.020	0.807	0.026
India	2006	-1.840	-0.044	-1.344	-0.031	-1.880	-0.044	-1.386	-0.031
India	2015	-0.237	-0.025	-0.038	-0.013	-0.271	-0.026	-0.073	-0.014
Jordan	2002	1.923	0.077	2.493	0.077	1.893	0.076	2.465	0.076
Jordan	2007	2.409	0.034	2.382	0.032	2.384	0.033	2.359	0.030
Jordan	2009	2.780	0.068	3.142	0.053	2.755	0.066	3.122	0.051
Jordan	2012	2.920	0.096	3.012	0.085	2.894	0.095	2.987	0.084
Kenya	2003	0.203	0.007	-0.291	0.005	0.169	0.006	-0.331	0.005
Kenya	2009	-0.166	0.010	-0.047	0.005	-0.202	0.009	-0.085	0.004
Kenya	2014	0.964	0.042	0.582	0.025	0.931	0.041	0.546	0.024
Kyrgyzstan	2012	1.735	0.024	1.676	0.034	1.707	0.023	1.647	0.032
Lesotho	2009	0.041	-0.025	-0.408	-0.040	0.008	-0.026	-0.442	-0.041
Lesotho	2014	0.072	0.011	-0.820	0.013	0.037	0.010	-0.865	0.013
Liberia	2007	-0.432	-0.080	-0.935	-0.056	-0.463	-0.081	-0.971	-0.057
Liberia	2013	0.485	-0.029	0.101	-0.038	0.455	-0.031	0.071	-0.039
Madagascar	2004	-1.909	-0.062	-2.214	-0.061	-1.949	-0.062	-2.259	-0.061
Madagascar	2009	-1.375	-0.058	-1.491	-0.066	-1.413	-0.058	-1.530	-0.067
Malawi	2000	-2.511	-0.086	-2.628	-0.084	-2.552	-0.086	-2.673	-0.084
Malawi	2004	-2.068	-0.077	-2.393	-0.063	-2.107	-0.077	-2.440	-0.063
Malawi	2010	-1.068	-0.014	-1.517	-0.025	-1.107	-0.014	-1.562	-0.025
Malawi	2015	-0.310	-0.022	-0.332	-0.024	-0.345	-0.022	-0.368	-0.024
Maldives	2009	1.205	0.069	1.359	0.099	1.172	0.068	1.319	0.099
Mali	2001	-1.199	-0.050	-1.119	-0.061	-1.236	-0.051	-1.155	-0.062
Mali	2006	-0.407	-0.027	-0.342	-0.023	-0.442	-0.028	-0.378	-0.023
Mali	2012	0.200	-0.065	-0.105	-0.048	0.171	-0.066	-0.135	-0.050
Moldova	2005	3.434	0.058	3.703	0.085	3.412	0.057	3.682	0.083
Morocco	2003	1.701	0.049	1.575	0.027	1.672	0.048	1.547	0.026
Mozambique	2003	-1.671	-0.032	-1.851	-0.037	-1.712	-0.032	-1.897	-0.038
Mozambique	2011	-1.042	0.000	-1.211	0.003	-1.081	-0.001	-1.257	0.003
Myanmar	2016	0.000	-0.017	-0.042	-0.004	-0.033	-0.018	-0.078	-0.005
Namibia	2000	0.410	0.030	0.356	0.007	0.375	0.029	0.322	0.006
Namibia	2007	0.368	0.024	0.216	0.011	0.334	0.023	0.179	0.011
Namibia	2013	1.297	0.037	0.927	0.012	1.267	0.036	0.896	0.011

		Without WHO data included				With WHO data included			
		Female		Male		Female		Male	
Country	Survey year	Size	Intensity	Size	Intensity	Size	Intensity	Size	Intensity
Nepal	2001	-2.730	-0.079	-2.091	-0.071	-2.772	-0.080	-2.134	-0.071
Nepal	2006	-1.911	-0.063	-1.343	-0.059	-1.951	-0.064	-1.381	-0.060
Nepal	2011	-1.236	-0.065	-0.599	-0.036	-1.272	-0.065	-0.635	-0.037
Nepal	2016	-0.525	-0.027	-0.129	-0.018	-0.560	-0.028	-0.164	-0.019
Nicaragua	2001	0.603	0.006	0.666	0.012	0.571	0.005	0.633	0.011
Niger	2006	-2.899	-0.103	-3.034	-0.098	-2.941	-0.103	-3.080	-0.098
Niger	2012	-1.151	-0.030	-1.234	-0.033	-1.189	-0.031	-1.275	-0.033
Nigeria	2003	-1.069	-0.029	-1.538	-0.052	-1.107	-0.030	-1.579	-0.052
Nigeria	2008	-1.247	-0.026	-1.783	-0.026	-1.286	-0.026	-1.830	-0.026
Nigeria	2013	-0.269	-0.032	-0.449	-0.045	-0.302	-0.033	-0.482	-0.046
Pakistan	2012	-2.422	-0.061	-2.483	-0.049	-2.464	-0.061	-2.532	-0.048
Pakistan	2018	-0.939	-0.028	-0.593	-0.041	-0.976	-0.028	-0.628	-0.041
Peru	2005	0.094	0.008	0.164	0.016	0.059	0.008	0.126	0.016
Peru	2008	0.241	0.036	0.481	0.035	0.205	0.035	0.443	0.035
Peru	2009	0.561	0.043	0.727	0.046	0.526	0.042	0.689	0.045
Peru	2010	0.483	0.051	0.781	0.061	0.447	0.050	0.742	0.060
Peru	2011	0.812	0.062	1.057	0.065	0.778	0.061	1.020	0.064
Peru	2012	0.823	0.066	1.281	0.065	0.788	0.065	1.245	0.064
Rwanda	2000	-1.156	-0.057	-1.328	-0.086	-1.193	-0.058	-1.363	-0.086
Rwanda	2005	-1.993	-0.061	-1.976	-0.062	-2.034	-0.062	-2.019	-0.062
Rwanda	2010	-1.084	-0.039	-1.086	-0.032	-1.121	-0.040	-1.126	-0.032
Rwanda	2015	-0.530	-0.012	-0.873	-0.013	-0.566	-0.013	-0.915	-0.014
Sao Tome	2008	0.371	0.065	0.082	0.067	0.334	0.064	0.036	0.067
Senegal	2005	1.269	0.012	1.545	0.019	1.240	0.011	1.518	0.018
Senegal	2010	0.944	0.020	0.670	0.001	0.913	0.019	0.638	0.000
Senegal	2013	1.483	0.032	1.371	0.040	1.454	0.031	1.339	0.039
Senegal	2014	1.432	0.040	1.466	0.056	1.402	0.039	1.433	0.056
Senegal	2015	0.980	0.048	1.322	0.040	0.947	0.048	1.290	0.039
Senegal	2016	1.482	0.076	1.501	0.071	1.449	0.075	1.466	0.070
Senegal	2017	1.563	0.062	1.737	0.059	1.532	0.061	1.705	0.058
Sierra Leone	2008	0.270	-0.037	-0.276	0.002	0.239	-0.038	-0.315	0.002
Sierra Leone	2013	-0.739	-0.010	-0.465	0.008	-0.776	-0.011	-0.506	0.007
South Africa	2016	0.668	0.065	0.946	0.048	0.632	0.064	0.910	0.047
Swaziland	2006	0.395	0.020	0.120	0.023	0.361	0.019	0.082	0.023

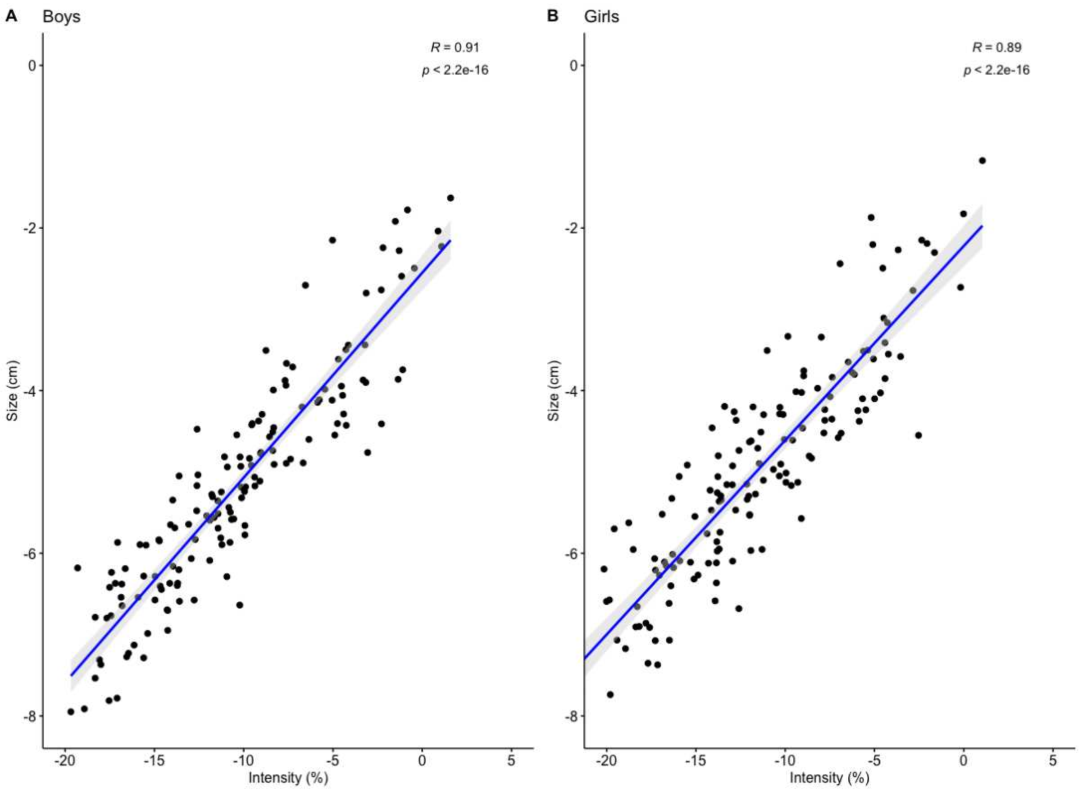
		Without WHO data included				With WHO data included			
		Female		Male		Female		Male	
Country	**Survey year**	**Size**	**Intensity**	**Size**	**Intensity**	**Size**	**Intensity**	**Size**	**Intensity**
Tajikistan	2012	0.092	-0.001	0.718	0.007	0.058	-0.002	0.686	0.006
Tajikistan	2017	1.572	0.011	1.805	0.022	1.545	0.010	1.780	0.020
Tanzania	2004	-1.364	-0.035	-1.348	-0.029	-1.403	-0.036	-1.391	-0.029
Tanzania	2010	-0.991	-0.001	-1.193	-0.035	-1.030	-0.002	-1.234	-0.035
Tanzania	2015	-0.279	0.002	-0.256	-0.008	-0.315	0.001	-0.293	-0.008
Timor-Leste	2009	-2.275	-0.084	-2.471	-0.076	-2.315	-0.084	-2.516	-0.076
Timor-Leste	2016	-0.460	-0.026	-0.567	-0.021	-0.495	-0.027	-0.606	-0.022
Togo	2014	0.435	-0.006	0.500	0.006	0.403	-0.007	0.466	0.005
Uganda	2000	-1.315	-0.019	-1.286	-0.038	-1.355	-0.020	-1.327	-0.039
Uganda	2006	-0.199	-0.012	-0.564	-0.024	-0.234	-0.013	-0.601	-0.024
Uganda	2011	0.004	0.023	-0.321	-0.011	-0.032	0.023	-0.359	-0.012
Uganda	2016	0.711	0.040	0.585	0.016	0.678	0.039	0.550	0.015
Yemen	2013	-1.929	-0.070	-1.690	-0.077	-1.969	-0.071	-1.729	-0.078
Zambia	2002	-2.167	-0.062	-2.130	-0.068	-2.208	-0.063	-2.174	-0.069
Zambia	2007	-0.980	-0.022	-1.427	-0.034	-1.018	-0.023	-1.469	-0.035
Zambia	2013	-0.509	0.002	-0.680	0.003	-0.546	0.001	-0.722	0.003
Zimbabwe	2005	-0.317	0.013	-0.766	-0.002	-0.354	0.013	-0.809	-0.003
Zimbabwe	2010	-0.135	0.023	-0.368	0.001	-0.172	0.023	-0.408	0.001
Zimbabwe	2015	0.498	0.053	0.478	0.037	0.462	0.052	0.440	0.037

Supplementary File 6: Scatter plot of the differences in the SITAR random effects for size and intensity parameters with versus without inclusion of the mean height of the WHO child growth standards in the multi-country dataset for boys and girls

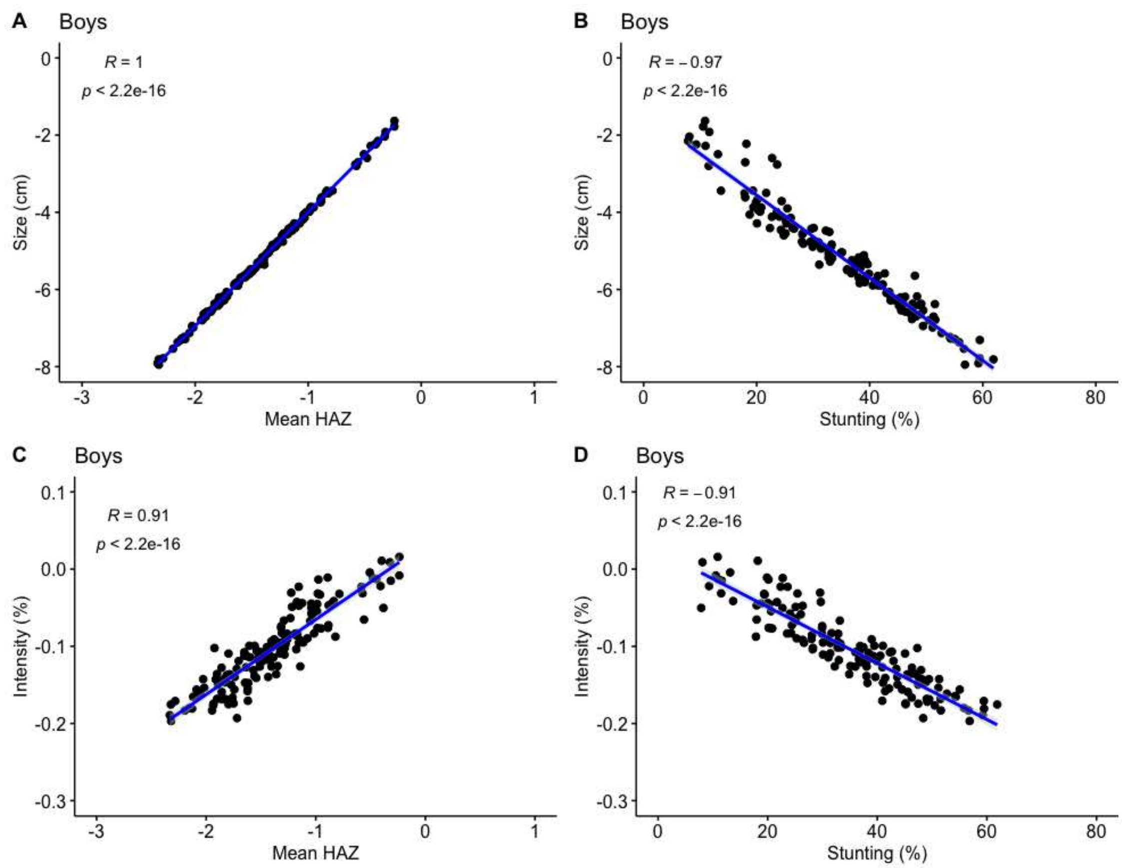


Difference = Without WHO data - With WHO data

Supplementary File 7: Scatter plot, correlation, and line of best fit (95% CI; shaded region) between SITAR size and intensity random effects (excluding WHO) for 145 Demographic and Health surveys from 64 countries for boys and girls

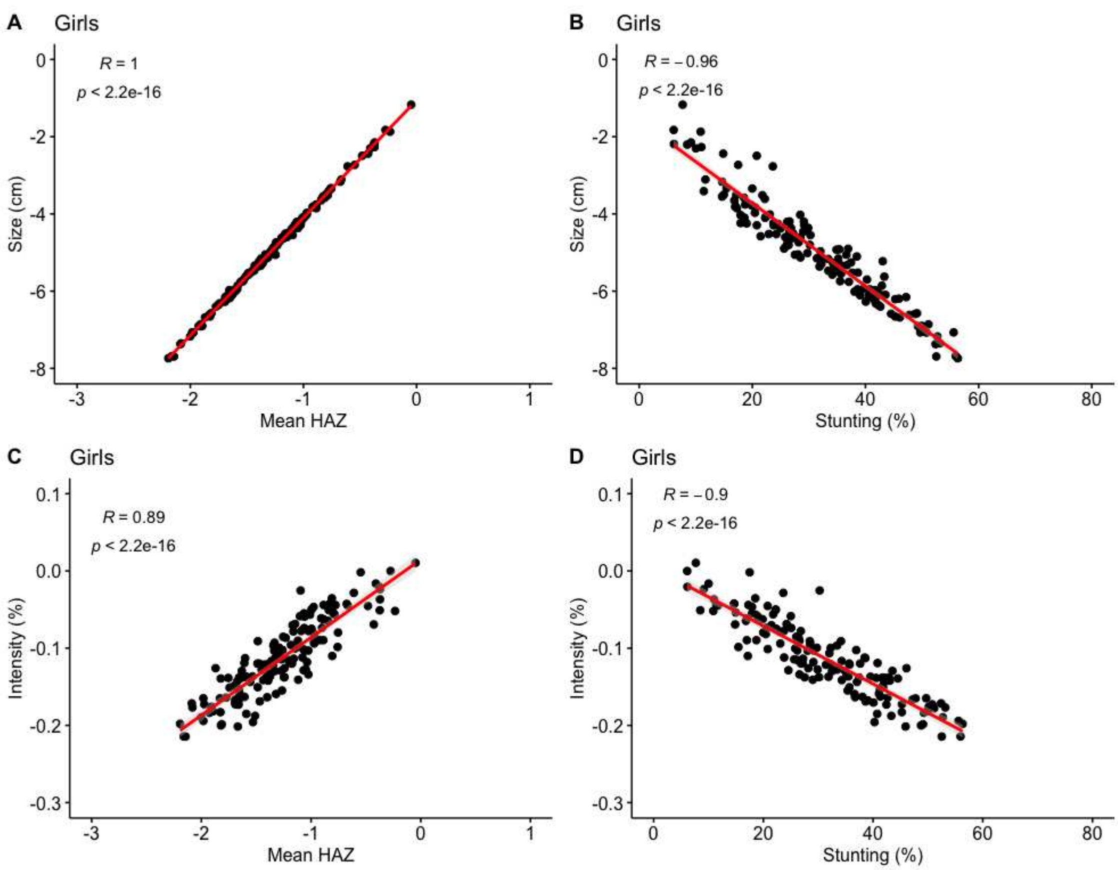


Supplementary File 8: Scatter plot, correlation, and line of best fit (95% CI; shaded region) between SITAR size and intensity random effects (excluding WHO) with stunting prevalence and mean height-for-age z-scores (HAZ) for boys



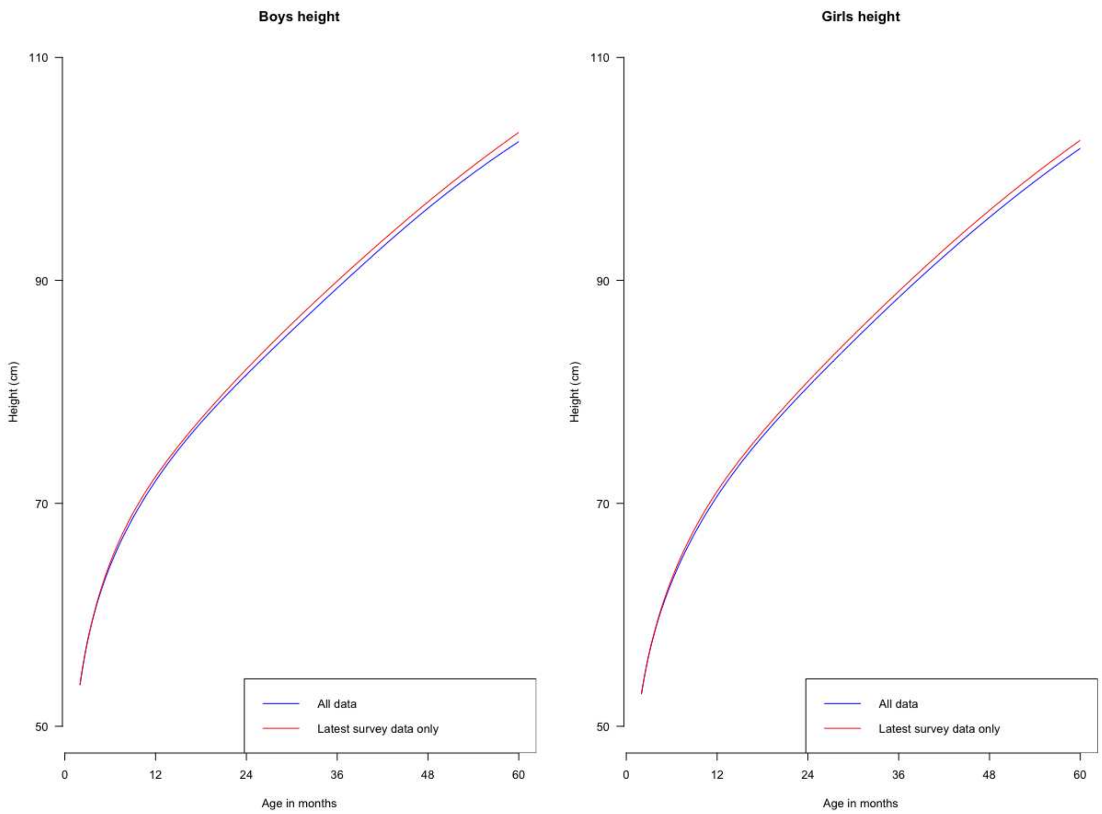
Ohuma EO, *et al. BMJ Global Health* 2021; 6:e004107. doi: 10.1136/bmjgh-2020-004107

Supplementary File 9: Scatter plot, correlation, and line of best fit (95% CI; shaded region) between SITAR size and intensity random effects (excluding WHO) with stunting prevalence and mean height-for-age z-scores (HAZ) for girls



Ohuma EO, *et al. BMJ Global Health* 2021; 6:e004107. doi: 10.1136/bmjgh-2020-004107

Supplementary File 10: Sensitivity analysis comparing the mean population growth curve using all surveys (n=145 surveys) compared to using only the latest survey in each country (n=64 countries): Boys (left panel) and girls (right panel)



Ohuma EO, *et al. BMJ Global Health* 2021; 6:e004107. doi: 10.1136/bmjgh-2020-004107

Supplementary File 11: A sensitivity analyses of SITAR models fitted to the Demographic Health Survey data of 145 surveys (64 countries) from 2000 to 2018 classified according to the World Bank regions

World Bank region classification	Percentage of variance explained by the fitted SITAR model	
	Boys (%)	Girls (%)
Sub-Saharan Africa (n=83)	70.3	69.0
East Asia and Pacific (n=7)	No convergence	No convergence
Europe and Central Asia (n=10)	No convergence	No convergence
Latin America and the Caribbean (n=21)	80.6	81.8
Middle East and North Africa (n=11)	83.9	80.7
South Asia (n=13)	70.0	71.3

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Supplementary File 12: Correlation and linear regression analyses of the SITAR size and intensity parameters with average starting height from birth to 2-months of age (proxy of fetal growth)

Model specification	Coefficient (95% CI)	Correlation	Adjusted R-squared
Boys			
Postnatal size vs Starting height at 2-months	0.56 (0.36 - 0.76)	0.41	0.165
Postnatal intensity vs Starting height at 2-months	0.67 (-0.11 - 1.44)	0.14	0.013
Postnatal size at 2-months vs Postnatal intensity	0.26 (0.24 - 0.28)	0.91	0.826
Postnatal size vs Starting height at 2-months + Postnatal intensity			
Starting height at 2-months	0.39 (0.32- 0.46)	N/A	0.903
Postnatal intensity	0.25 (0.23 - 0.26)		
Girls			
Postnatal size vs Starting height at 2-months	0.64 (0.41 – 0.86)	0.43	0.177
Postnatal intensity vs Starting height at 2-months	0.84 (-0.04 – 1.72)	0.16	0.017
Postnatal size vs Postnatal intensity	0.24 (0.22 – 0.27)	0.89	0.791
Postnatal size vs Starting height at 2-months + Postnatal intensity			
Starting height at 2-months	0.44 (0.35 – 0.53)	N/A	0.876
Postnatal intensity	0.23 (0.22 – 0.25)		

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